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ABSTRACT

Problems and possible solutions for training Papua New Guinea undergraduates to think creatively are considered, with a focus on engineering students. Since many engineering graduates in Papua New Guinea work in isolated outposts with no one to teach them on the job, a practical problem-solving emphasis is needed in their college courses. Engineering students also need to study social, ethical, and political topics, since human problems compound engineering problems. Presently, education for engineers follows the traditional method of teaching, much of which involves rote learning. In order to produce creative and inventive engineers, attention should be focused on the process and performance of the overall system as well as results and details of operations, and methods of inquiry as well as knowledge. Cultural and educational influences in the country that affect engineering education include: accounting for the unknown in supernatural terms; a tendency to approach the world with certainty or ready-made formulas rather than doubt; education that provides few precedents for experimentation with new materials, designs, or approaches; little exposure during childhood to books and modern toys; Papua New Guineans' difficulty with certain mathematical concepts; and English language deficits. (SW)

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THINKING -BREAKING AWAY FROM CONVENTION

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1. The Need for Creative Thinking in Engineering in Papua New Guinea

In Papua New Guinea as in other Third World countries which are rapidly undergoing a technological revolution, the young engineer may find himself in a position of responsibility far greater than his western counterpart of the same age. At the present level of industrial development, most of the graduate engineers (civil, electrical and mechanical) would be expected to undertake:

(a) field and workshop supervision
(b) project planning and control
(c) drafting of specifications
(d) simple design modifications
(e) material, electrical and mechanical testing.

Normally, in the industrialised world, an engineering course at university is designed to prepare the engineer to a sufficient level of competence to start learning in industry. However, a considerable proportion of our graduates must be seen as likely to be manning isolated outposts with no one to learn from and a consequent strong need for self-reliance. This justifies the view that a highly practical problem -solving emphasis should be given to the courses.

Even in the private sector where there has been much less localisation of manpower than in the public sector and even in the main centres such as Port Moresby, the capital, or Lae, the main industrial city, a relatively young and inexperienced engineering graduate may find himself having to solve a problem by 'making do' without access to the proper part or equipment; while out in the bush or in the village situation improvising solutions would be the normal order of the day.[1] In the village too the young engineer must find solutions to engineering problems that are appropriate to the level of the village situation, i.e., which can be handled by the relatively unsophisticated villager once set in motion. Appropriate technology is practically a new philosophy of engineering and is still, relatively speaking, in its infancy.[2]

Compounding the engineering problems in the village situation are seemingly intractable human problems. As a fellow-Papua New Guinean the young engineer may well be the only person with any chance of successfully negotiating with the villagers. The villagers may say they want development (a new road, more forestry activity, an airstrip, mini-hydro, etc), but they may well be infuriatingly reluctant to give up their piece of land for the sake of it. The PNG villager has a very strong

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attachment to his land. Burton-Bradley explains this role in psychological terms:

> 'In the course of my work in Papua New Guinea, I have become aware that the indigenous person has a psychological attachment to his land transcending the purely economic and legal arrangement of the superimposed culture, however liberal the latter may be. I find that he may go along with the formal arrangements in order to please, but in his thinking and at a deeper level his basic attitude to what is his land remains substantially unchanged throughout his life, independent of any transactions which may have taken place. His land is the place where he was born, where he was subjected to primary enculturation, where he has lived the most important aspects of his life, where the values of his cultural-linguistic group have been constantly reinforced, and where in most instances he may die. As he grows up he learns that it is the place where his ancestors preceded him, and to which they may return, thus giving the attachment a magico-religious sanction. It is the place where his children will follow. At the psychological level it is clearly an extension of the concept of self.'

In such a context, it is clear that one cannot study engineering in isolation from human social, ethical and political considerations.

In a country like Papua New Guinea too one is dealing with engineering problems of a new magnitude because, for example, of difficulties of terrain and remoteness. The new gold and copper mining complex at Ok Tedi close to the border with Irian Jaya in the far west of the country has been described as among the most challenging feats of engineering ever undertaken by man. At present it is true that expatriate engineers are in charge, but there is a commitment to localise as far and as fast as possible and in the future when there are other Ok Tedis in PNG comparatively young engineers can expect to undertake increasingly responsible roles. Much the same can be said of road construction, hampered as it is by mountainous terrain, voluminous rainfall, landslides, earthquakes and sheer remoteness.
Even in Lae city itself (population 62 000), a number of private companies have been totally localised (e.g., the glass factory, the petrol drum and container factory) and have young engineers in full charge. There is evidence that their superiors in the parent companies expect them to be innovative in the name of economy.

It is clear from all this that simply 'knowing about' engineering is insufficient. Creative thinking will be required on the job. By creativity we mean some such definition as that proposed by Shirley Olsen in Group Planning and Problem-Solving Methods in Engineering Management (p 8): 'In the context of design, creativity is the discovery of combinations of principles, materials or components that are especially suitable as solutions to the problem at hand.' (Olsen (ed), 1982) Our experience is that young Papua New Guinean students prefer to learn by rote and

are very reluctant to offer innovative ideas in the sense defined. If this is the case in the relatively secure and supportive environment of the university classroom, how likely is it that they will be prepared to come up with creative solutions to problems under stress in the field?

Let us now examine engineering education in PNG as it now exists and as it needs to be to meet graduates' professional requirements as outlined above.

2. Engineering Education in PNG

Formal education in PNG begins at the age of seven and primary schooling lasts six years. It is not free and therefore not compulsory and the percentage of school-age children who actually attend school or who complete the six years of primary education varies according to the facilities available in any given area. Some 30 000 children a year graduate from Grade 6 of Community Primary School. The majority simply drop out of the education system. High School education lasts four years-up to Grade 10. Some 8 000 students over the whole country emerge at the end of Grade 10; only 10% find a place in one of the country's four National High Schoools. National High School (NHS) lasts two years (Grades 11-12), is residential and is designed as a preparation for tertiary education. Students study a number of subjects for national Grade 12 examinations. Entry to university is competitive and depends on getting good grades in all subjects, especially mathematics and science in the case of prospective engineers. About 50% of NHS students go on to University, of whom between 80 and 100 would enter the common Foundation Year in Engineering course at the PNG University of Technology (Unitech). Perhaps 60 to 80 would complete the four year course and become Bachelors of Engineering in the field of civil, electrical or mechanical engineering which they had specialised in for three years after Foundation Year.

The need for training at a lower level-that of technician - is covered by the Technical Colleges, entry to which is gained at Grade 10. Here the programme consists of sandwich-pattern courses requiring in-college training of twenty weeks per year. Undergraduate engineers by contrast spend only about twelve weeks in all in industry during breaks between full-time studies, prior to taking up postgraduate employment. Many students are sponsored by particular companies such as the mining companies, the National Broadcasting Commission, Post and Telecommunication, the Electricity Commission, Air Niugini, the Department of Civil Aviation, industrial organisations, etc.

School education, especially in earlier years, is largely rote learning. But even at University level there is a good deal of 'chalk and talk', backed up by more or less comprehensive handouts. Tests and examinations tend to be based closely on lecture notes, heavily guided laboratory experiments, plus reading of the textbook (if there is one). The tutor's emphasis tends to be on imparting information; the students'

on learning and regurgitating this. In final year, students are required to undertake a piece of individual research and report their results both orally and in writing. This is one of the few places in the entire course where individual initiative is called for.

We suggest that the kind of engineering education outlined above is an inappropriate approach for PNG.

What then is the necessary mental outlook to be built into our engineering education system?

To meet the development needs of the country, two types of engineering professional are required. These are the technician and the graduate engineer. The former are trained to acquire technical knowledge, operational skills and to produce results. The latter need to be trained to be creative and innovative so as to break away from the conventions.

Professor Matsuda, keynote speaker at the AEESEA Regional Conference in Thailand in December 1983, identified some seven pairs of contrasting mental approaches in order to achieve these respective goals. By referring to these and contrasting the education required by the technician and the technologist, we can perhaps spell out what needs to be done.

1) Answer-oriented vs question-oriented

An effective technician is able to correctly answer a technological question that requires an answer. At the moment our students are taught to provide answers to a set of questions. They need to be trained how to ask relevant questions which will lead to obtaining a precise answer.

2) Solution-oriented vs problem-oriented

An able technician can solve a given problem whereas a competent engineer must be able to formulate a problem. The former is a much easier and faster process to achieve; the latter would require skills and experience as the problem may not be well defined and requires gathering sufficient information on which to base the solution.

3) Operation-oriented vs objective-oriented

An operation-oriented task is well-defined and set out in such a way as to meet specific objectives without any particular attention being paid to the value and meaning of the objectives. A talented technician must possess this mentality and these skills in order to perform satisfactorily.

The objective-oriented task means that the objective itself is in question and one is required to define, search and evaluate in order to attain the objective.

It is necessary and important for our technician to master all operations so that the objective(s) can be achieved. However, engineering education for the creative engineer must pay special attention to definition and evaluation of objectives.

4) Result-oriented vs process-oriented

A technician's performance is evaluated by the result of the operation. He is held responsible solely for the output. What is inside the 'black box' is of no concern to him as long as his output meets the required standard and specification. In many ways, he has no control over the process.

A creative engineer's role is different. He is held responsible for the structure of the process and is able to manipulate and change the result when he sees fit. The object is to obtain better or optimum results. Engineering education must provide the latter with strong fundamental knowledge so that students have an insight into the entire process.

5) Detail-oriented vs system-oriented

Technicians are trained to be detail-oriented as they are responsible for the detailed operation and its result. Engineering education must therefore provide them with such details with the proviso that over-teaching should be avoided and only the very fundamental matters of the subject should be effectively learned.

Engineers on the other hand must be concerned with total performance of the overall system. To this end, these students must be taught by the system-oriented approach encompassing a wide range of related disciplines. Economics, social science, environmental sciences must be taken into consideration, especially with regard to the introduction of new technology. Engineers also consider the details but from a system viewpoint. These details can then be rank-ordered in accordance with the contribution of each detail to the system so that priority evaluation among the details can be made.

6) Knowledge-oriented vs methodology-oriented

Irrespective of the type of engineering professionals (technicians or engineers) produced, success or failure of an endeavour depends upon the amount of in-depth knowledge they possess. The more know-how a technician possesses, the better and faster will he be in operating or repairing the system. Hence engineering education must ensure these students are provided with the optimum amount of knowledge.

A good engineer should be able to create new knowledge itself. For this he relies upon a knowledge of methods of inquiry and methodology. It is pertinent to note that knowledge may become obsolete as technology advances, but methodology continues to be effective and useful for a considerably longer period.

7) *Storage-oriented vs retrieval-oriented*

It is commonly accepted that someone thinks he has knowledge when information is stored in his brain and the memory capacity is sufficient for the amount of information he needs to carry out his job. As technology advances, there is a danger that information becomes so voluminous that the individual memory can no longer cope.

An engineer needs an information-handling system structure. Because he is trained in methodology and able to ask relevant questions, he can draw on sufficient and necessary information from appropriate sources.

The PNG National Manpower Planning Assessment Report (1981) indicates clearly that the demand for both technicians and engineers considerably exceeds the supply. Engineering education programmes must be designed to meet the needs of the country. Th present situation is such that education for engineers still follows the traditional method of teaching, much of it through rote learning. In order to produce creative and inventive engineers, more attention must be given to shifting the focus of orientation firmly toward the right hand side of each spectrum.

To understand the factors inhibiting such a shift, we now need to look at the students' cultural background in some detail.

3. *Cultural Background*

PNG has a population of some 3.5 million, about 1000 tribes with differing cultures and over 700 languages (ie. about one quarter of the world's languages and only 0.07% of the world's population!). Until the period of continuous white contact (at most about 100 years and in many areas less than half of that), people lived in small, relatively isolated communities practising subsistence farming and/or fishing in a Stone Age lifestyle which included intertribal warfare, belief in sorcery, and sometimes head hunting and cannibalism. Despite some trading between coast and highlands and between island and island, knowledge of the outside world was minimal. White men were in many places greeted as tribal ancestors returned from the dead; their advanced technology as a form of magic. In the space of only about twenty years it is possible for a student at the PNG University of Technology (Unitech) to have moved from a remote Stone Age village through Community School, High School and National High School to a situation where he is studying, say, theory of plasticity. The title of Sir Albert Maori Kiki's autobiography, Ten Thousand Years in a Lifetime, succinctly sums up the experience of many of his fellow-countrymen.

Given the staggering diversity of cultures and languages, one may feel hesitant to offer any generalisations at all. However, this very cultural and linguistic diversity has attracted a steady stream of linguists, sociologists and anthropologists to PNG from Malinowski and indeed even before, to the extent that there is now the standing joke that the average Papua New Guinean family consists of a father, mother, half a dozen children and an anthropologist! On the basis of our admittedly somewhat

limited acquaintance with the not inconsiderable body of sociological, anthropological and linguistic literature, we can perhaps hazard a number of generalisations, always bearing in mind that they are generalisations and not necessarily universals.

3.1 Traditional Education

In the village setting, education would typically involve the young child for a number of years informally observing his elders at work, performing such tasks as cooking, house building, weapon manufacture, making and playing musical instruments, preparing for and performing public celebrations, canoe building, gardening, carving, pottery, basketry, bilum making, bridge-building, etc. The child would no doubt attempt to copy adult practices and even be encouraged to join in. At a later stage, towards puberty, there would be a formal 'rite of passage' to initiate the young person into the adult community. The object of these often painful ceremonies is clearly to impress powerfully on the initiate's mind certain knowledge, lore and received wisdom as well as to test valued attributes such as courage and endurance, all vital to the continued survival of the tribe within a more or less hostile environment. The important factor in all this from the standpoint of western education is that at no point is the young learner expected or encouraged to innovate. Indeed, innovation might well be frowned on as a rebellion against the superior knowledge and power of the elders. He/she is called upon to observe, learn and reduplicate received knowledge and tribal mores. Romola MacSwain has put it thus in her study of the people of Karkar Island, The Past and Future People:

> 'New knowledge could be obtained only through dreams or revelations, or by purchase, but not through human intellectual enterprise.' (Macswain, 1977).

In modern PNG it might be argued that the importance of such traditional education is declining. Those children nowadays brought up in urban centres such as Port Moresby or Lae or even in smaller townships like Madang, Rabaul, and Wewak, are largely divorced from the village educational tradition. While it is incontrovertible that an urban elite (using as its language Melanesian Pidgin and to some extent English in preference to vernacular) is in process of formation, it must be stressed that the vast majority of the population remains rural and that it is perfectly possible for our university students to reach university without having acquired any great familiarity with town life. (The country's four National High Schools, though within striking distance of an urban centre in each case, are nevertheless rural boarding schools in the heart of village communities.)

Testimony to the continuing intellectual and spiritual importance of traditional education for Papua New Guineans is, however, abundant in anthropological literature. Even more significant, there is testimony 'from the inside'. Michael Somare, father figure of independence and twice Prime Minister, tells us in his autiobiography Sana how much it meant to him even as a sophisticated western-trained adult to undergo

traditional tribal initiation. (His father had been a village chief - he himself glories in the name of 'the Chief' to this day). Bernard Narakobi, lawyer, philosopher and advocate of 'the Melanesian Way' as an antidote to what he considers corruptive in western culture and society, writes: 'I have just returned from the University of Melanesia. That University is the village.' (Narakobi, 1983). One of the country's leading poets and dramatists, John Kasapwailova, has written eloquently of traditional cultural values before the corrupting influence of the white man. Kiki (op.cit.) tells movingly how 'I feel cheated somehow, when I remember that I never underwent the Miro awa akore, that I never sat in the hehe eravo, and that no Orokolo girl ever marked me "as her tree".' (p 54)

These men come from a wide spectrum of Papua New Guinean society-Narakobi and Somare from the Sepik area in the NE; Kasapwailova from the Trobriand Islands in the SE; and Kiki from Gulf Province in the SW. Yet all are in essential agreement as to the value of traditional education.

It would be wrong to conceive of Papua New Guinean village society as completely static. Paula Brown in her study of Chimbu society, A study of Change in New Guinea Highlands, speaks of a strongly felt sense of flux. 'It is rather as though they feel that the world is always changing and unpredictable.' (Brown, 1972). Nevertheless, by western standards - especially western technological standards-the whole ethos is one of preservation and perpetuation rather than deliberate innovation. The young Papua New Guinean villager is undoubtedly required to think but he is not encouraged to think innovatively. Anyone who innovates or succeeds in becoming 'big' puts himself at risk.

Transfer all this to the western-style school and university environment, and the teacher or lecturer becomes the village elder, the fount of all wisdom, the exemplar whom you aspire to copy. You expect him to tell you what to do in a crisis and how to understand the world. You certainly do not challenge his authority with impunity. Even within a western-style primary education, especially when run under religious auspices, the teacher/missionary was unlikely to encourage challenge (especially on matters of faith which loomed large in such an education). It cannot be overemphasised that the kind of critical thinking deemed necessary for success and perhaps even survival today in the west is utterly at variance with all that the young Papua New Guinean has imbibed from his traditional culture and even his schooling during his formative years. We are demanding no less from him or her than an intellectual revolution. Yet Maxwell (Thinking: The Expanding Frontier) has observed: 'Educators should continually remind themselves that deeply held beliefs may play a greater role in how we respond to opportunities to learn....than we have acknowledged so far.' (Maxwell, ed., 1983).

3.2 Traditional Certainty vs Modern Uncertainty

The picture of the traditional Papua New Guinean world view built up by anthropological research into Papua New Guinean societies is one of certainty. It is a limited world geographically and as a result a limited world in terms of 'information load.' What is not 'known' is at least 'accounted for' in supernatural terms. For example, death and illness are not understood in terms of western medical knowledge; but neither are they incomprehensible. Rather they are interpreted as the result of sorcery and it is even possible to divine who has been responsible and exact revenge (in the case of death) or take counteraction (in the case of illness). Even the unexpected intrusion of the white man into this relatively circumscribed universe was satisfactorily accommodated by reference to the ancestors' return. Thus the traditional world is a self-consistent world of practical knowledge backed up by myth, legend and magic. As Fitzpatrick and Kimbuna put it in the conclusion to their recent study of the Bundi people:

> 'From the time they were young to the time they died, they knew everything that was expected of them in their universe.... Now they say there is nothing definite.' (Fitzpatrick and Kimbuna, 1983).
> John Kimbuna is himself a Bundi so this is powerful and persuasive testimony.

When the missionary came, he proclaimed a new certainty-that of Christian doctrine, faith and salvation. The scientist and technologist, by contrast, introduced a strong measure of doubt into the intellectual world of the young Papua New Guinean. Mind-boggling concepts such as the aeons of geological time, the distances of intergalactic space, the micro-world of the sub-atomic particle, the acclerated world of the computer performing a myriad calculations in next to no time-all this could be accepted as 'fact.' Yet we of the west admit to ignorance in so many spheres. We have as yet only contending theories to offer as to the origin of the universe; while Darwinian evolution is generally accepted today, there are still uncomfortable gaps in the evidence; there is controversy concerning conservation, the population explosion, the energy crisis; we seem unable to solve international economic and political problems equitably and amicably; we may even, as a species be hell-bent on nuclear suicide (as far as western man is concerned) and nuclear murder (insofar as we involve the rest of humanity along with us).

Nothing in traditional education in PNG could prepare the young Papua New Guinean to trade certainty for doubt in this fashion. It is therefore hardly surprising that he/she is reluctant to abandon the security of the ready-made formula in favour of revolutionary designs that must allow for a substantial 'factor of ignorance.'

3.3 Learning Transfer

One of the key values of western learning is its transferability to new situations. It is understood fundamentally as an evolving body of knowledge-not a closed circle. We work from the known to the unknown. We expect our previous knowledge and experience to take us only so far - and then we must have the courage to adapt and innovate. (The great medieval cathedral builders in Europe were prepared to push technology quite literally to the point of collapse).

The traditional village setting by contrast would appear to throw up few novel experiences. To western eyes indeed village life is repetitive to the point of dulness. Recent research into Papua New Guinea intellectual development (eg., Lancy, 1983) would seem to indicate that certain universally attainable intellectual potentials are not well promoted within at least some village cultures in PNG. Because there is little apparent desire to change village lifestyle radically, he argues, 'this means that the education system must bear the entire burden of transporting individuals from the Stone Age to the Computer Age' (Lancy, 1983).

Thus in a world where little of the unexpected takes place, the need for a learning strategy that allows for transfer to novel situations is not powerful. On the whole then their traditional educational background provides our students with few precedents for experimentation with new materials, designs or approaches. Knowledge rather is seen as relatively 'fixed' in relation to largely predictable demands. Hence, the tendency to rely on rote learning.

3.4 Cargo Cult

In several parts of PNG, contact with Europeans gave rise to a 'cargo cult'. It may well be that the residual effect of this movement so far as some students are concerned is that western technology retains a flavour of the magical. Whatever rational explanations are offered, one part of the student's mind may continue to reject these explanations. (One remembers that in desperation Europeans in earlier days sometimes flew representative villagers to large centres to try to show them where the cargo really came from and were quite nonplussed when the village people continued to believe that the cargo came from some sort of ancestral 'heaven' accessible only to the white man.) If there is any such lack of trust at base in the good faith of the teacher, it is unlikely that the student will be motivated to take over and utilise imaginatively the ideas taught. The 'cargo cult mentality', wherever it survives, induces an attitude of 'take and use', not one of 'understand, adapt and extend'.

3.5 Concept of Time

Concepts such as biorhythms and internal body clock mechanisms might well be held to have universal applicability, but the more conscious awareness of the passage of time seems to vary considerably from one society to another. In a paper on 'The concept of Time in Peasant Society', Professor Ahmed M. Abou-Zeid of the Anthropology

Department of the University of Alexandria has said:

> 'Time is seldom regarded by villagers in these societies as a mere tool that should be exploited in achieving certain well-defined objectives or a mere means of measuring activity and productivity. It is also a means of consolidating existing social relationships and establishing new ones.... Evans-Pritchard once asked whether the pastoral Nuer "ever experienced the same feeling of fight against time or of having to co-ordinate activities with an abstract passage of time, because their points of reference are mainly the activities themselves, which are generally of a leisurely character".'

In such contexts, haste may be seen as a positive discourtesy.

It is a commonplace criticism of our students that they 'work slowly'. Equally, it is a common complaint by our students that they 'do not have enough time to cover the work'. There is evidence of incredibly long - one would suspect unproductively long - study hours at Unitech.

Alvin Toffler has documented the accelerated pace of life in the west in recent times and suggested that for some people stress is almost like a drug. They crave it almost as they would tobacco or alcohol. But one suspects that in the Papua New Guinean context the extra factor of time-stressed study is not conducive to creative thought. It is one more massive readjustment that we demand of our students.

3.6 'Culture Deficit'

This is a contentious area but it seems to us that we must at least try to confront the issues if we are to understand the problems of our students. Let us say at the outset that in our opinion 'deficit' in relation to so-called 'primitive' societies can only have meaning vis-à-vis an <u>external</u> culture. It does not imply any intrinsic culture deficit. A culture with any serious inbuilt deficits would surely never have survived. When we talk of 'culture deficit' in relation to the young Papua New Guinean, we mean something like the following:

The western child at an early age has access to many toys which encourage innovative thinking. One thinks of Meccano and Leggo, model aero kits, electric train sets, and nowadays even computers. More often than not, father gets as great a pleasure from such toys as his young son and joins in the improvisational activities on the floor! The western child also has early access to books. Toys and books it would seem are of crucial value in developing a child's creative potential and we suspect it would not be too difficult to show that a western child deprived of such stimuli could suffer a cultural deficit within his own culture. The Papua New Guinean child has no access to sophisticated western toys in the main and even today far too little access to books. From the point of view of operating within a western educational tradition and perhaps especially within an engineering framework, he/she is seriously deprived of

much valuable intellectual stimulation.

3.7 'Mathematical Deficit'

There is a growing body of evidence that Papua New Guineans have difficulty with certain mathematical and mathematically-related concepts. Clements and Lean (1981) conclude their study 'Influences on Mathematical Learning in PNG: Some Cross-cultural Perspectives' thus:

> 'Because national children have not grown up in an environment in which line drawings, photographs or audio visual experiences are commonplace, they are disadvantaged, in comparison with expatriate children, if asked to perform tasks which involve recognition and interpretation of features in line drawings, photographs, and audio-visual presentations.'

Clarkson's study (1983) of Year 12 students' mathematical performance in the 1980 and 1981 external examinations points out:

> 'The pre-requisite ideas for algebra are only presented in Year 9. Thus Papua New Guinean students simply have not had time to complete the many examples in algebraic manipulations that western students have completed by the time they are introduced to "Calculus" and "Vectors".'

Atawe Koigiri (1984) sums up an analysis of 'Year 12 students' Mathematical Performance on the 1982 External Examination' with this cry from the heart:

> 'It is clear that the topics of "Sequences and Series", "Vectors" and "Calculus" still remain the hardest topics in the major course. One really starts to wonder how much students learn about these topics.'

Chris Wilkins in a paper for this year's PNG Mathematics Education Conference discussed disappointing results from a mathematics competition run at Unitech in these terms:

> 'Has the competition been a success? I would have to say no. It has not generated the response that I hoped it would and it has therefore not fulfilled the main intention of a mathematics competition, which should be to encourage problem solving in the student body. It has unfortunately reinforced my, and other people's, belief that our students are not good problem solvers. I would suspect, without any proof, that many of the students would be able to solve many of the problems if the problems were set as part of a course, because in this situation the students would be keyed on to the solution technique. Without such cueing they would seem to find it hard to devise a satisfactory strategy.'

Clarkson again (1983) in his introduction to a paper on 'Types of Errors Made by PNG students' neatly sums up recent work of the PNG Mathematics Education Centre of which he is director:

> *'A number of reports have compared the mathematics capabilities of Papua New Guinean students with various western groups and have either made global judgements lamenting their inability to cope with elementary mathematics (Edwards and Bajpal, 1979), or have tried to go further and distinguish more closely those particular areas of mathematics in which these students lag behind their western counterparts. Sullivan (1980) in discussing Edwards' results showed that both groups were comparable when the problems were of straightforward arithmetical calculations; the PNG students had great difficulty, however, once word problems were attempted.*
>
> *Various other areas have been investigated, such as spatial ability, memory and cognitive tasks at various levels, and these have been related to factors which seem to delay national students' achievements in mathematics (see Bishop, 1979; Clement and Lean, 1980; Souviney, 1981). Some specific work in the reading of mathematics suggests that this may well be another area of concern (Jones, 1981).'*

Compounding all this, there are deficiencies in the actual physical conditions within which PNG High School students attempt to learn mathematics and which Naomi Wilkins (herself a national teacher of mathematics) described in a recent paper as 'shocking as well as frightening.' (Wilkins, N, 1984).

There can be little doubt therefore that students enter upon tertiary training on a much less secure mathematical footing than, on average, do European undergraduates. Engineering studies, of course, are heavily slanted towards mathematical interpretation/ solution of problems. We suggest this mathematical insecurity is just one more factor inhibiting the development of innovative thinking.

3.8 'Language Deficits'

3.8.1 English Language Deficit: English is the first language of only a handful of our students, usually the offspring of mixed European/Papua New Guinean parentage. In addition, a few elitist parents in the city bring their children up to speak English somewhat in the manner of the Russian aristocracy bringing their children up to speak French in the nineteeth century.

English is often described as a 'second' language in PNG, but until the recent emergence of an urban elite using Tok Pisin as a first language this was unlikely to be accurate for more than a few students. The typical villageborn student would begin life speaking his mother's tongue; would also acquire his father's vernacular which might be a separate (though related) language; move on to a smattering of other

neighbouring village languages; come to use Tok Pisin as a lingua franca; and learn English only when he/she went to school. The likelihood would be for the use of Tok Pisin to grow throughout his schooldays outside the classroom, while he continued to develop English within it. Only the most academically successful schoolchildren would master English and this might will be at the expense of the vernacular languages which because of the small numbers speaking each (typically only a few thousand) would be of less and less viability the higher he/she climbed the educational ladder. At some point Tok Pisin would become the language of preference with English the second language. (In Papua, Hiri Motu might well take preference over Tok Pisin). From the point of view of order of acquisition, English is rarely the second language of our students. It is a third, fourth or even fifth language! It is only in terms of importance or frequency of use that, at a more or less advanced stage of education, it becomes the second language.

Despite this, English is the language of education even from Primary School. An earlier generation of students had the advantage in at least some cases of being taught by native-speaking expatriate teachers. Today primary education is entirely in the hands of Papua New Guinean teachers whose own command of English is variable. At worst, the primary school child acquires the rudiments of education in a language barely used outside the classroom from teachers who themselves have not much better than an advanced primary school child's command of the language. Two things follow: to survive in the classroom, the teacher indulges in a good deal of rote-style teaching; and the pupil likewise to survive indulges in a good deal of rote-style learning and other subterfuge tactics that mimimise exposure of real non-comprehension. 'Nurts are bields that are used for globbing things together. Mathias, what is a nurt?' 'Sir, a nurt is a bield and is used for globbing things together.' 'Correct, Mathias. Well done!' This is quite a possible classroom exchange. Given an early indoctrination of this type, is it likely that a student will be willing to indulge in the perilous pleasures of creative thinking at university? He is more likely to continue using survival tactics to disguise ignorance. It takes considerable courage to say: 'I do not understand.'

3.8.2 Vernacular 'Language Deficit': The linguist Whorf coined the term Standard Average European (SAE) to refer to those languages which share a substantial world view. Thus, the French or German student, say, who has to read some part of his technological studies in English, is still operating within a largely similar cultural context and can to some extent use these shared cultural assumptions to compensate for his/her linguistic deficiencies. Not so the Papua New Guinean student with one of the 700 Papua New Guinean vernaculars as his base.

Linguists tend to make the assumption that all languages are equal, i.e., that no language is superior or inferior to any other as a vehicle for expressing thought and feeling. This seems to us a doubtful though kindly meant assumption. No one would surely claim that, say, tools for digging the ground before planting-from

digging stick to mechanical plough - are equally efficient. It is all too easy to forget that languages, like tools, are a human invention. One may assume that no language falls below a certain level of efficiency for its functions but the testimony of bilinguals is by no means on the side of those who regard languages as fully equal. The genuine bilingual admits a preference for one language over another for specific purposes.

One would not wish to be too adamant as it is a highly controversial, indeed sensitive, area. But one cannot help but be impressed with the claim that the middle-class American schoolchild of, say, six or so is well on the way to a command of approaching 14000 words, two and a half times the known inventory of quite a number of Papua New Guinean languages. (See Lancy, 1983). The highly trained adult native speaker of English could eventually wield a vocabulary of at least 30 000 and possibly 60 000 words - i.e., up to twenty times the size of some vernacular vocabularies. It is hard not to believe that the availability of so many more words does not make wider thinking possible.

But the problem for the vernacular-based Papua New Guinean is not only the paucity of vocabulary. It is the incredible difference in world view embodied in English as compared with vernacular. Almost the entire apparatus of technological thought would have to be acquired through English as there is no parallel in vernacular.

Vernacular languages tend to classify the objects in the environment in a fundamentally different way from SAE languages - a way that the eminent Australian expert on PNG languages, Stephen Wurm, has described as 'a sometimes bewildering range of references to the number, etc. of the subject, direct and indirect object, and beneficiary of an action... Nouns often display complex class systems.' (Wurm, 1983).[3]

This is not to say that the advantages of such classifications are all on the side of English. As Peter Mühlhäusler, himself an eminent student of the PNG linguistic scene, has wittily pointed out: 'English and other SAE languages are particularlylacking in classifiers.' He compares English with Aiwo (spoken in the Reef Islands of the South West Pacific) which has about forty noun classes, comparable to gender. 'According to Wurm (1981) one such class, signalled by the prefix si- , is that of nouns denoting objects and items which are despised, unclean, not valuable, dangerous or unpleasant .... It is interesting to imagine the effects if such noun-classifiers were obligatary in English. Advertising would certainly be affected. Advertisers would find it much harder to foist undesirable products on an unsuspecting public and si-garettes would not even need a government health warning.' (Mühlhäusler, 1983).

Nevertheless, there seems to be a strong tendency towards a binary rather than hierarchical classification in PNG languages. If this is indeed the case for even a significant number of vernaculars, it would seem on the face of it to pose a problem for such speakers in moving to a system of classification such as in English especially

in the area of science and technology which depend so heavily on hierarchical classification.

3.8.3 The Pidgin Position: The problem with Tok Pisin is that it is a relatively young (though fast-developing) language. To quote Muhlhaüsler (1983) again: 'One of the fundamental insights of language planning is that, in times of rapid societal and technological upheaval, language changes tend to lag behind other developments. This insight is widely ignored by mainstream linguists who continue to believe that speakers of any language can express whatever they want to.' Given the time and the will on the part of its speakers, there seems no intrinsic reason why Tok Pisin should be incapable of developing a full technological register. There is considerable evidence that Tok Pisin is increasingly used among themselves by our students not only in social contexts but also in technological discussion.

The difficulty lies in the fact that the technological terms (and accompanying concepts) are all first learned in English and then transported into Tok Pisin. Because of the students' English deficit (3.8.1 above) there can be no guarantee that the concepts were fully understood in the first place before transfer. The tendency is not to search for a Tok Pisin equivalent, but merely to transfer (and possibly phonologically adapt) the English term. For example, we asked Third Year engineering students what was the Tok Pisin for 'second law of thermodynamics' and the answer was 'sekan lo av temodainamiks.'

On the positive side, it must be said that our students come from a highly adaptable multilingual background. Native speakers of English are all too inclined to think of monolingualism as the norm. World wide, multilingualism is more probably the norm. On the negative side, Tok Pisin could be more of a snare and delusion than a help in clarifying technological concepts by reason of its deceptive similarity to English. We may believe - and so may our students - that they have understood more than they really have.

As we have admitted, the linguistic evidence is by no means clearcut, but taken overall it is hard to avoid the conclusion that the extreme - possibly unique- linguistic complexity in PNG is unlikely to be conducive to student confidence in creative thinking in English. And we simply do not yet know how far it is possible to use vernacular or Tok Pisin as a basis for creative technological thinking.

3.9 The 'Primitive Culture Deficit'

The term 'primitive' is very freely used about many aspects of PNG society by expatriates in general and even by professional authropologists and sociologists. There has been a strong tendency to view Papua New Guineans not as human beings like the the rest of us but as some kind of survivors from Mankind's collective past. This view is naturally and justly resented by Papua New Guineans to such an extent that at least one provincial premier has banned anthropologists from his territory unless they

can establish that their studies will be of value to Papua New Guineans and not just a ticket to a PhD back home.

Though linguists refrain from using the term 'primitive' about any language, there is still a tendency to see PNG as a linguistic laboratory rather than a country full of very human human beings. Even Wurm fell into this trap when he used the very term 'linguistic laboratory' in the title of a recent book (Wurm, 1979).

Whatever carefully worded definitions of 'primitive' we dream up, however justified linguists may feel in using terms like 'linguistic laboratory', the net effect on the educated Pupua New Guinean can only surely be a negative one. A Scots engineering student may feel free to innovate because he knows he has a long and honourable engineering tradition behind him. How helpful would it be in building up his self-confidence if he knew that many scholars as well as ordinary people throughout the world regarded his language and culture as 'primitive'?

We would suggest that such terminology is counterproductive and should be dropped if any headway is to be made in encouraging PNG students to think innovatively with confidence.

4. Some Approaches to a Solution

In this paper we have argued that PNG requires young graduates capable not only of mastering and regurgitating what they have been taught but of adapting this to the solution of new problems. We have attempted to outline and estimate the magnitude of the forces militating against any such development of creative engineering. What are the possible solutions to this problem?

1) Creativity must be stressed earlier in the educational system than university level. At every level there is a frantic urge to 'give them the facts' and leave creative thinking to develop on its own. Time must be made for creative work in science and in other subjects. There used to be a 'clear thinking' course in the English programme in National High Schools. There was also recently an abortive attempt to introduce a cross-curricular study called 'Design and Technology.' Perhaps both of these require re-evaluation. An ongoing series of conferences on the theme 'Problem-Solving Through the Curriculum' may also have a contribution to offer here.

2) Related to this, problem solving at a relatively simple level must precede tough problem solving tasks. It is pointless to lead students to a high level of factual knowledge by spoonfeeding methods and then suddenly switch to asking them to think creatively.

3) Instead of emphasising the supposed (or even real) deficiencies of PNG society, an attempt should be made to build on its strengths and real achievements, including

those in the field of technology. For example: building of huge traditional haus tambaran and longhouses (see Ruff, R and W.M, 1980)

bridge construction (see Siegel, 1982)

ocean going canoe building (see Doran, 1981)

Pacific navigation (see Lewis, 1978) etc

4) Time is on the Papua New Guineans' side. The next generation of students - some the sons and daughters of the present generation - will presumably be much more 'at home' in the world of technology and relatively less inhibited by traditional cultural restraints on creative thinking.

5) Instead of fighting Tok Pisin (as some lecturers wish to do), we should help PNG students in the task of sharpening up the language to accommodate technology. The very work of doing so will force them to think about the exact meaning of technological concepts. It is very easy to parrot; adequate translation demands understanding.

6) English is used a lot more widely in PNG today than under the Australian regime. Three national newspapers as well as the bulk of radio programmes go out in English. It is to be hoped that students' command of English may improve rather than decline in future. If this does take place, they will use English more confidently. We suggest the current need is for highly educated bilinguals - bilingual, that is, in English and Tok Pisin.

7) Role-playing has proved a successful means in some courses for getting students to think creatively. There is a strong dramatic trait in the PNG character and this can be exploited in the learning situation. Freed from the hesitancies they may feel in their own personalities, young Papua New Guineans can be remarkably inventive and insightful when playing the role of, say, consultant engineer or member of a board of inquiry into some environmental issue.

8) English studies should be task-oriented. The language taught must include not only terminology and structures for description of objects and engineering processes, but the language of evaluation and problem-solving as well. In recent years, moves have been made in this direction. Foundation Year Engineering students are asked in their English course not only to describe, say, several models of clothes peg, but to decide which is the best design solution. Or again, a visit to a factory to observe and report on an engineering process also involves an element of appraisal. Should the glass factory be resited nearer the limestone quarry (limestone being a primary ingredient of glass)? Or, should further automation be introduced into the manufacture of petrol drums and containers?

9) At all stages, supportive and sympathetic teaching is called for. The expatriate lecturer must learn to be patient and start where he finds the students to be, rather than simply lamenting deficiencies and blaming someone further down the line.

10) Getting a degree should not be seen by students as the end of the educational road. The aim should be for continuing education. In-service courses must be offered by the universities, concentrating on creative approaches to problems within a liberating, stress-free role-play format.

11) Throughout the education system there should be less formal classroom teaching. One cannot expect creative thinking as the end-product of a system where 'telling' is the norm.

12) We would also wish to endorse Bruner's plea on behalf of problem-finding as well as problem-solving in the classroom (Bruner, 1968).

5. Conclusion

In her thought-provoking novel about the nature of education, The Prime of Miss Jean Brodie, Muriel Spark insists that the business of education 'is and always has been to put old heads on young shoulders.' Presumably, old heads are 'thinking heads.'

Maxwell (op.cit.) has argued that 'despite the cultural universality of the teaching of thinking skills, there is general agreement that all societies, without exception, today do a poor job of teaching problem-solving skills that are necessary to live in the modern world.' Hence, no doubt, the worldwide interest in de Bono's proposals reported at the Fiji Conference on Thinking in 1982.

It would be nonsense to suggest that western universities are full of innovative engineering (and other) students, while Third World universities such as Unitech have only rote learners. Western students are also no doubt stigmatised by their tutors as unimaginative, uncreative, etc - for whatever reason. Our contention in this paper is a much simpler, more defensible one. For cultural reasons, we have argued, students in PNG face particularly acute problems in learning to think innovatively. In western technological enterprises, the current trend is towards group problem-solving methods (see, for example, Olsen (ed.), 1982). As Olsen says in her Preface, 'This is an emergent attitude that has grown out of dissatisfaction with mechanistic models and purely quantitative methods which have been unsuccessful in dealing with social issues, product systems, communications, and environments having far reaching effects on large segments of society.' We have seen, however, given the relatively small number of graduates and the scale and remoteness of the terrain, that our graduates may well find themselves on their own as the only fully trained engineer for miles around. They must therefore be prepared and able to solve problems by themselves.

We have taken engineering as the example subject, but our colleagues in other areas of technology are concerned at the same problem. If we have succeeded in satisfactorily identifying and accounting for the difficulties, we have also hopefully

made a start towards their solution. There is little doubt what the aim must be.

We should be grateful and interested to hear from others teaching in like circumstances how far their students' problems mirror ours, as well as to learn how the problem of training undergraduates to think creatively is being tackled elsewhere.

NOTES

1 Several organisations have attempted to prepare engineering material for the 'bush' situation, for example, The Melanesian Council of Churches, publishers of Liklik Buk and Volunteers in Technical Aid, with their handbook VITA.

2 See, for example, Professor Dunn; and the Canadian Hunger Foundation publication Experiences in Appropriate Technology. The Papua New Guinea University of Technology has an Appropriate Technology Development Institute which publishes reports on its activities.

3 John Jones has an interesting study, Classification Systems, Vernacular and Education in Papua New Guinea (1976). His conclusion was that though classification systems in PNG Vernacular are very different from those in English 'students are perfectly capable of generating their own hypotheses, setting up their own classification systems, producing their own ideas, taking decisions for themselves, etc, if only they are given the opportunity.' The biggest inhibiting factor was rote-style teaching with its concomitant expectation of rote-style learning.

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